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Laboratory and Field Tests of Pond Sealing by Chemical Treatment

University of Tennessee Agricultural Experiment Station

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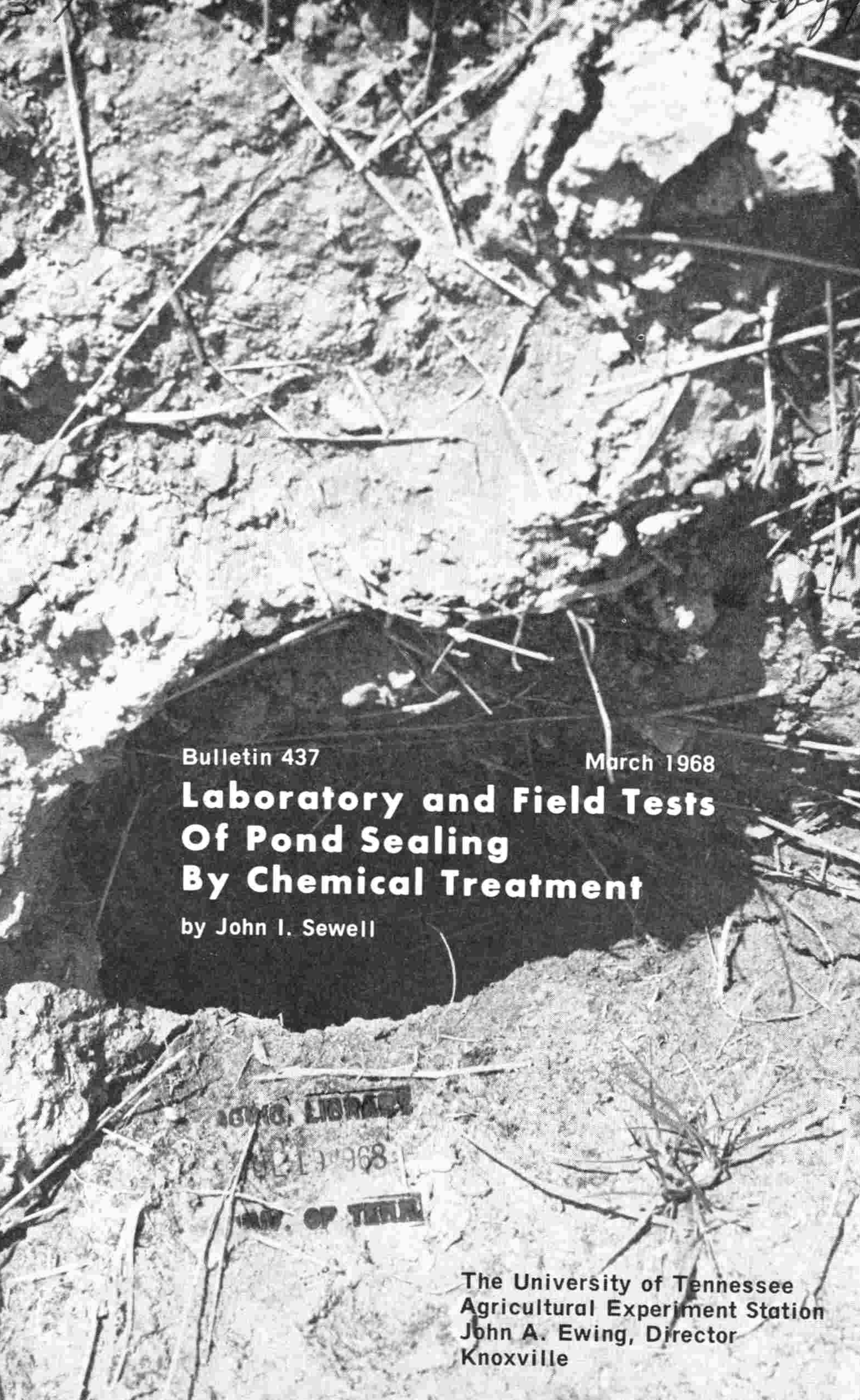

Bulletin 437 March 1968

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by John I. Sewell

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SUMMARY

Chemical treatments alone will not solve all pond-sealing problems. First, proper engineering principles should be applied to the design and construction of any pond. The greatest potential for a chemical treatment is as a supplementary sealing measure to be applied when properly designed and constructed ponds still do not hold.

Since the chemical and minerological makeup of soils and the chemicals dissolved in surface water vary widely with location, the effects of a given chemical treatment will also vary with location. Sodium carbonate or sodium pyrophosphate offered the best possibilities as dispersing agents for the soils treated in this study. Tests indicated that thoroughly pulverizing the soil of a pond floor by mechanical means is most important before field applications of chemicals.

Chemical dispersing agents can reduce the mechanical strength of a pond floor; therefore, blowouts are more likely to occur where porous substrata are present. These studies suggested that, for a 10-foot head of water, porous strata should be covered with at least 1 foot of silt or clay material if chemical treatment is to be used. Field experience indicates that the blanket may need to be 2 feet or more in thickness.

Of the 9 seriously leaking ponds treated, 8 of the treatments were successful (Table 5). Serious blowouts developed in one pond, and it was repaired. Although the repair was not a complete success, the pond has held at least 5 feet of water since the repair.

The leakage rates of the treated ponds did not appear to increase with time; if anything, they seemed to decrease. The water of treated ponds became quite muddy after treatment; however, the ponds treated in this study tended to become clear within 2 or 3 years after treatment.

The sodium carbonate treatments at 5 tons per acre and the sodium pyrophosphate treatments at 2 tons per acre appeared to be about equally successful. The chemical cost for each of the two treatments varied between $325 and $400 per surface acre treated. With the current emphasis on high rates of production and efficient operations, expenditures in this amount may be justified for small ponds where sources of water are badly needed.

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By
John I. Sewell[1]

INTRODUCTION

Many Tennessee ponds never hold water or go dry during periods of drought. Pond failures are almost always expensive and inconvenient, especially when ponds are expected to supply water for irrigation, livestock, or domestic needs. In many areas of East and Middle Tennessee, ponds do not hold satisfactorily.

For many years various methods have been used in attempts to seal leaking ponds. Blanketing and compacting leaking portions of pond floors with from 1 to 2 feet of the least pervious soil material available has often been used with fair to good results. Allowing hogs or cattle to puddle the soil of a leaking pond has on occasion been shown to reduce water seepage rates. Blankets of bentonite and similar high swelling clays are almost always effective in sealing ponds; however, the high tonnage requirements of these materials result in prohibitive transportation costs when the materials are not available from nearby quarries. Plastic or vinyl liners have been used with varying degrees of success. However, the liners can be expensive, and the labor requirements for their installation are high. For many situations, it seemed that better solutions to pond sealing problems might be found.

During recent years, a few laboratory tests and field trials of pond sealing with chemicals have been conducted in the United States; however, most of these were of limited scope and short duration. Almost none of this work was done in Tennessee.

The results of these tests varied widely. Chemicals suitable for sealing ponds are now more readily available, and higher ex-

[1]Assistant Professor of Agricultural Engineering. This bulletin describes work done under University of Tennessee Agricultural Experiment Station Project H-219, "Pond Sealing," and University of Tennessee Water Resources Research Center Project A-003, "Small Reservoir Sealing."

penditures for obtaining dependable sources of water supply may be justified under today's changing agriculture. The results of laboratory tests and field trials suggest that pond sealing by chemical methods offers excellent possibilities of becoming an economically feasible practice in many situations.

HOW CHEMICAL DISPERSING AGENTS WORK

Excessive pond leakage is usually caused by 1) highly aggregated or granular soil in pond floors; 2) channels through or under limestone or sandstone; or 3) exposed strata of gravel, coarse sand, or chert. Chemical treatments alone will not usually reduce leakage caused by the latter two. Thus chemical treatments are most effective where the soils are highly structured but have high specific surfaces as do silts and clays.

The most widely used soil dispersing compounds contain sodium. When sodium compounds are added to an agricultural soil as a dispersing agent, the sodium replaces the calcium, hydrogen, and magnesium on the soil through ion exchange. This results in the soil having a high percent sodium saturation. A sodium saturation of 20-80% is desired with the higher level of sodium saturation tending to last longer. The sodium ions, being highly hydrated, help destroy the structural units of the soil aggregates. This dispersed mass of individual clay particles and very small aggregates then settles on the pond floor with a high degree of orientation forming an almost impermeable layer. Lambe (7)[2] gives a detailed discussion of these exchange reactions and the resulting changes in physical properties. Soil dispersion can theoretically be accomplished by chemical or mechanical means; however, this bulletin considers only chemical means.

The writer is aware of no reports that water in chemically treated ponds has been harmful to livestock, fish, or aquatic vegetation. Gleason, **et al** (4), in **Toxicology of Commercial Products**, list $Na_4P_2O_7$, Na_3PO_4, and Na_2CO_3 as moderately toxic; that is, the probable lethal dose for a 150-pound man is between 1 ounce and 1 pound. However, the sodium compound when mixed with the soil remains in the soil and diffuses very slowly into the pond water.

[2] Numbers in parentheses refer to appended references.

CHEMICALS AND SOILS TESTED

The chemicals tested and their approximate costs in Tennessee follow:

Name	Formula	Cost/ton
Sodium pyrophosphate	$Na_4P_2O_7$	\$190
Sodium tripolyphosphate	$Na_5P_3O_{10}$	200
Sodium hexametaphosphate	$NaPO_3$	260
Sodium tetraphosphate	$Na_6P_4O_{13}$	285
Sodium carbonate (soda ash)	Na_2CO_3	65
Sodium phosphate (tribasic)	Na_3PO_4	90
Sodium chloride (salt)	$NaCl$	30
Sodium hydroxide (lye)	$NaOH$	145

Many other effective dispersing compounds were not considered in this study because of their high costs.

Table 1 gives physical data on the soils tested. The soils were taken from areas in Tennessee where pond sealing problems are prevalent. For the various horizons of Armour (30- to 35-inch depth), Fullerton (24- to 30-inch depth), and Hartsells (10- to 14-inch depth) soils, in milliequivalents per 100 grams, the cation capacities varied from 9.3 to 9.8; exchangeable acidity from 5.5 to 7.7; exchangeable calcium from 1.4 to 2.3; and exchangeable magnesium from 0.6 to 0.9.

Table 1. Physical data on soils tested

Soil Series	Province	Depth Inches	Mechanical analysis[1] Sand	Silt	Clay	Max. density[2]
				Percent		Lb./cu. ft.
Armour	Central Basin	30-35	24	50	26	104
Braxton	Central Basin	24-30	23	40	37	94
Colbert	Central Basin	24-30	17	35	48	94
Decatur	Valley and Ridge	30-32	12	24	64	
Dunmore	Valley and Ridge	0-6	19	52	29	
		12-18	18	40	42	
		66-72	16	32	52	
Fullerton	Valley and Ridge	0-6	41	46	13	101
		6-12	36	41	23	95
		24-30	18	26	56	90
Hartsells	Cumberland Plateau	10-14	37	38	25	104
Pembroke	Highland Rim	32-40	23	32	45	103
Sequoia	Valley and Ridge	0-6	24	35	41	90
		54-60	30	20	50	94

[1] Chert and gravel greater than half an in. were removed prior to making analysis.
[2] Maximum Standard Proctor density, dry basis.

LABORATORY PROCEDURE

The soil samples were air dried for 1 week. All stones greater than half an inch were removed by sieve. The samples were then separated into 1-cubic-foot lots, pulverized, and placed in a mixer for half an hour to insure uniformity.

The chemicals were thoroughly mixed with a sample of air-dry soil. In calculating the rate of chemical application, it was assumed that the chemicals would be mixed into the top 6 inches of the soil. The soil-chemical mixture was packed into a standard 1/30 cubic-foot permeameter to a density which was as close as possible to 90% of Standard Proctor. This value was chosen because no better compaction is usually achieved in the construction of small reservoirs. Using a 10-pound drophammer device, a suitable compaction technique was developed by trial-and-error for each soil type.

The moisture content of the air-dry soil was determined. After loading the permeameters, the weights of the compacted soils in the permeameters were determined so that the compacted densities could be computed and then compared with their respective 100% Standard Proctor values.

Upon closure of the permeameters, tap water from a constant-head supply was applied. The head of the permeameters was 12 feet. The discharge rates of the permeameters were determined approximately three times per week. Before taking discharge rates, the system was bled of any entrapped air which had collected. Since computations indicated that evaporation losses of permeameter effluent were insignificant compared with the total volumes of effluent, evaporation losses were neglected. Using these discharge rates, the geometry of the permeameters, and the hydrostatic head with Darcy's law, the permeability rates were computed.

LABORATORY TEST RESULTS

The effectiveness of chemical treatments was evaluated largely on the basis of the resulting reductions in permeabilities of the samples. It was usually necessary to take permeameter discharge rates for 30 or more days before the discharges approached the steady-state condition. Figure 1 gives typical fluctuations of discharge rates with time for an effective treatment.

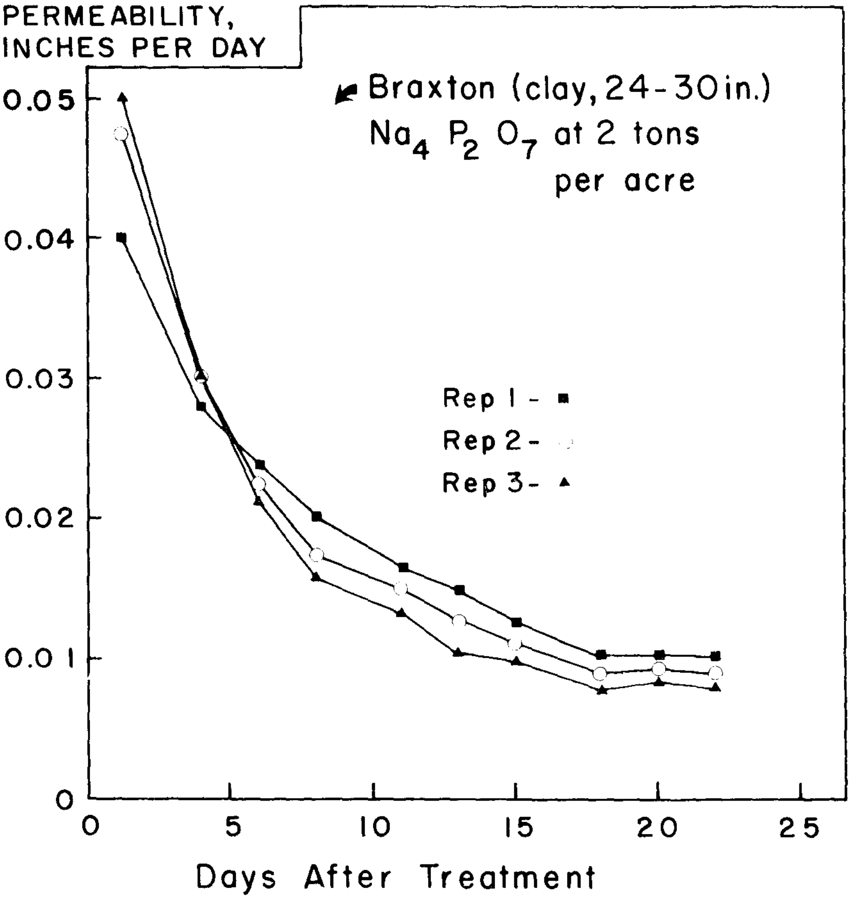

Figure 1. Typical changes in permeability rates with time for replications of an effective treatment.

In most of the tests, three replications of each treatment were made. Usually the discharge rates did not vary appreciably between replications. Figure 1 gives typical differences of discharge rates between replications of an effective treatment. Where the discharge rates varied widely between replications, additional tests were run.

In tests where the treatments were ineffective, the permeability rates (hereafter K) always tended to increase after a period of time. This point is illustrated in Figure 2 where Armour silt loam 30 to 35 inches deep was treated with sodium chloride at 5 tons per acre. However, for effective treatments, K values always tended to decrease with time as is shown in Figure 1.

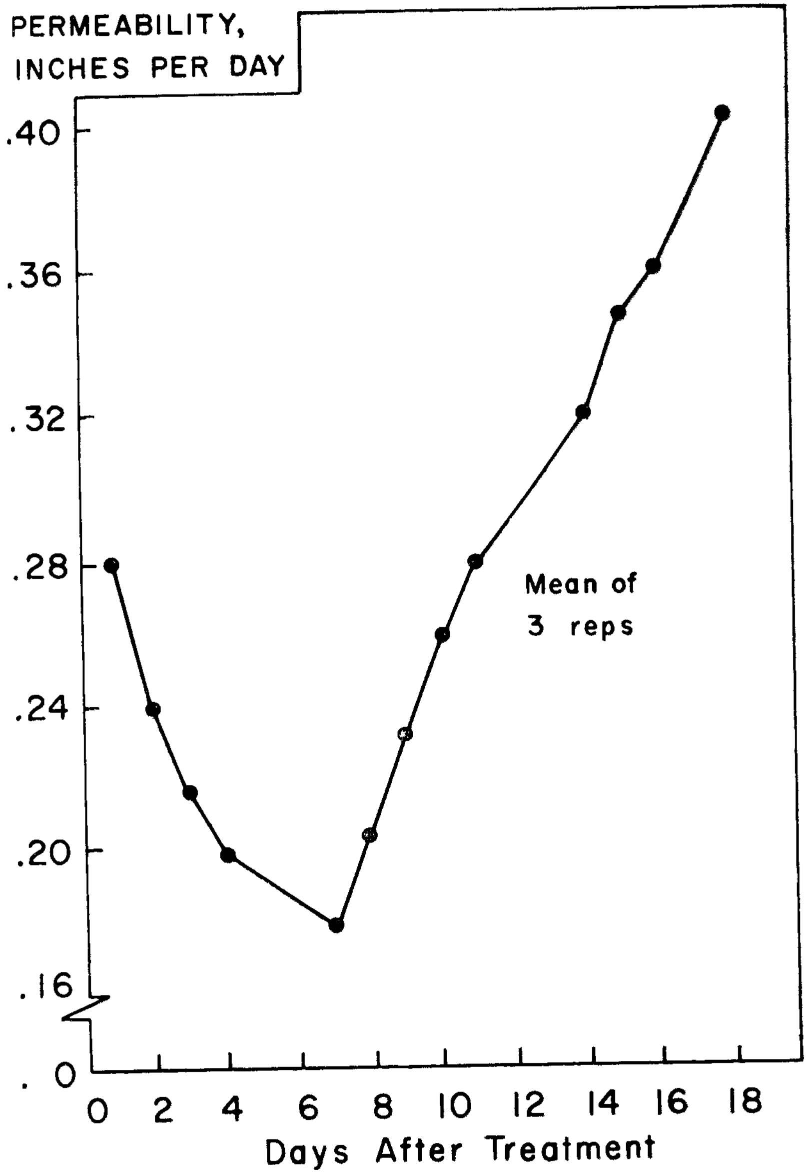

Figure 2. Changes in permeability of a soil column of Armour silt loam 30 to 35 inches in depth after treatment with sodium chloride (salt) at the rate of 5 tons per acre.

Obviously K is related to the compacted density of a sample. The densities of the sample varied from a low of 85% of Standard Proctor for unpulverized samples of Sequoia (6-inch depth) to a high of 96% for Fullerton subsoil (24- to 30-inch depth). The average value for all tests was 89.3% of Standard Proctor.

Table 2 gives results with the chemical treatments using soils pulverized before treatment. The K values can be compared with 0.012 inch per day, a value which has been used by Fonner (3) of the Soil Conservation Service as "the maximum permeability of an effective seal blanket." Lambe and Anderson (8) used 0.033 inch per day. Because it was assumed in the permeability computations that all material below the 6-inch treated seal blanket has infinite permeability, somewhat lower rates of chemical application than these data suggest might provide an effective seal.

Table 2. Mean permeability rates in inches per day for pulverized soil samples treated with several chemicals

Chemical	Treatment rate: (tons/acre—six in. depth)[1]						
	0	1	1.5	2	3	3.5	5
	Armour (Silt Loam, 30-35 in.)						
Sodium pyrophosphate	.77	.23		.047	.013		.002
Sodium tripolyphosphate	.77	.27			.020		.003
Sodium hexametaphosphate	.77	.69					.011
Sodium tetraphosphate	.77	.68					.031
Sodium carbonate	.77	.43		.24	.15		.052
Sodium chloride	.77	.50[2]					.41[2]
Lithium carbonate	.77						.0027
	Braxton (Clay, 24-30 in.)						
Sodium pyrophosphate	.46			.020			
Sodium carbonate	.46						.020
	Colbert (Clay, 24-30 in.)						
Sodium pyrophosphate	.28			.0073			
Sodium carbonate	.28						.0083
	Decatur (Clay, 30-32 in.)						
Sodium carbonate	.26						.042
	Dunmore (Silty Clay Loam, 0-6 in.)						
Sodium pyrophosphate	.23		.016				
Sodium carbonate	.23						.010
	Dunmore (Silty Clay, 12-18 in.)						
Sodium pyrophosphate	.65			.018			
Sodium carbonate	.65						.019
	Dunmore (Clay, 66-72 in.)						
Sodium pyrophosphate	.055			.0055			
Sodium carbonate	.055						.020
	Fullerton (Cherty Loam, 0-6 in.)						
Sodium pyrophosphate	.58	.017		.0053			
Sodium phosphate	.58			.028		.010	.0077
	Fullerton (Cherty Loam, 6-12 in.)						
Sodium pyrophosphate	.22	.005		.010			
Sodium carbonate	.22			.030			.016

Table 2 (Continued)

Chemical	Treatment rate: (tons/acre—six in. depth)[1] 0	1	1.5	2	3	3.5	5
	Fullerton (Cherty Clay, 24-30 in.)						
Sodium pyrophosphate	.12	.017		.0046			.00017
Sodium tripolyphosphate	.12	.016		.0054			
Sodium phosphate	.12					.0040	.0036
Sodium carbonate	.12	.042		.025		.010	.0013[3]
	Hartsells (Loam, 10-14 in.)						
Sodium pyrophosphate	.50	.10	.021	.017		.0034	.0027
Sodium tripolyphosphate	.50	.25	.110	.019		.0044	.0027
Sodium hexametaphosphate	.50			.050		.050	.0040
Sodium tetraphosphate	.50		.051	.028			
Sodium carbonate	.50			.26		.12	.035
Sodium chloride	.50			.38		.30[2]	.30[2]
Sodium hydroxide	.50		.189		.009		.002
Lithium carbonate	.50						.003
	Pembroke (Clay, 32-40 in.)						
Sodium pyrophosphate	.25	.051		.005			
Sodium carbonate	.25			.059			.003
	Sequoia (Clay, 0-6 in.)						
Sodium pyrophosphate	.39	.020		.010			
Sodium carbonate	.39					.008	.005
	Sequoia (Clay, 54-60 in.)						
Sodium pyrophosphate	.42			.017			
Sodium carbonate	.42						.019

[1]The rate is equivalent to tons per acre when the chemical is mixed in the soil to a depth of 6 in.
[2]K increased with time.
[3]At 10 tons per acre, K = .00088.

In the tests on Armour, Fullerton, and Hartsells, several chemicals were used. Based on these tests and considering the costs of the chemicals, sodium pyrophosphate and sodium carbonate showed the most promise. For this reason, only these two chemicals were used in most of the other tests.

For Armour silt loam, 30 to 35 inches deep (Table 2), and assuming that K = 0.012 inch per day is a satisfactory rate, the tests indicate that about 3 tons[3] of sodium pyrophosphate per acre-6 inches would be necessary. According to Figure 3, a treatment of about 7 tons of sodium carbonate per acre was equally effective. Figure 3 also shows that extremely high rates of chemical treatment do not cause a reversion of sealing effects.

The results of sodium chloride treatments on Armour are given in Figure 2. K decreased for about 1 week, and then it

[3]If the chemical is mixed in the soil at a depth of 6 inches, the rate is equivalent to tons per acre.

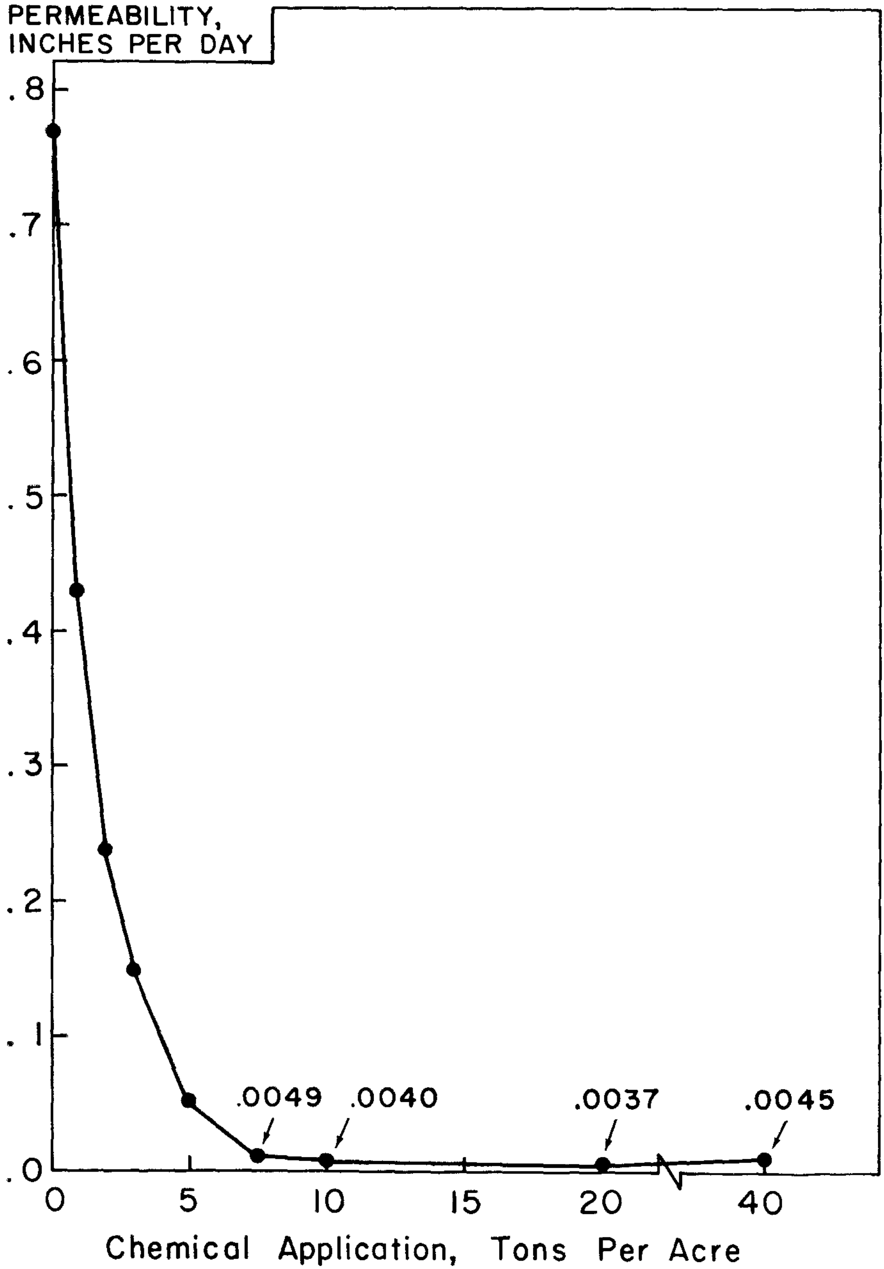

Figure 3. Permeability of soil columns of Armour (silt loam, 30 to 35 inches) after treatment with different amounts of sodium carbonate.

rapidly increased with increasing time. A plausible explanation of this phenomenon follows: With the sodium chloride treatment, the activity of the exchanged ions was not reduced; thus calcium and magnesium may have replaced the sodium which left the physical properties of the soil similar to those of the original untreated soil. An exchange reaction involving sodium carbonate or a sodium phosphate produces calcium carbonate or a calcium phosphate, both of which are very insoluble. Fonner (3) also observed the temporary sealing effects of sodium chloride.

For Braxton as well as Colbert, the sodium pyrophosphate treatments at 2 tons per acre were equally as effective as the sodium carbonate treatments at 5 tons per acre. However, the Colbert, containing montmorillonitic clay, appears to be more easily dispersed than is the Braxton.

In the tests on Dunmore, the effects of the treatments did not vary appreciably with soil depth. The sodium pyrophosphate treatments at 2 tons per acre were as effective as the sodium carbonate treatments at 5 tons per acre.

For Fullerton, sodium carbonate and sodium pyrophosphate appear to be about equally suitable. The effectiveness of the treatments was approximately similar for the several Fullerton horizons tested.

The results of the tests on Hartsells soil suggest that sodium pyrophosphate is probably the most effective dispersing agent of the sodium phosphates tested.

Tests on Pembroke and Sequoia soils suggest that the chemical dispersing agents tested should be effective in reducing pond seepage rates in these soils also.

The structural development within a soil before applying chemical tests obviously affects the resulting permeability. The B-horizons of Dunmore, Pembroke, and Sequoia had strong blocky structures. Since these samples were pulverized in the tests reported in Table 2, the resulting permeability rates obtained would have probably been higher had the soils not been previously pulverized. Tests on pulverized and unpulverized samples of Sequoia (Table 3) illustrate this point. The chemical treatments were much more effective where the soil structure was first partly destroyed by mechanical action. This clearly demonstrates the need for thoroughly pulverizing by mechanical means the soil of a pond floor in making field applications.

Table 3. Mean permeability rates in inches per day for Sequoia subsoil (clay, 54-60 in.) pulverized and unpulverized before chemical treatment

Chemical	Pulverized	Treatment rate (tons/acre) 0	2	3	5
Sodium pyrophosphate	Yes	.42	.017		
Sodium pyrophosphate	No	.61	.091	.010	
Sodium carbonate	Yes	.42			.019
Sodium carbonate	No	.61			.21

High-swelling clays such as bentonite are known to be effective pond sealers; however, the cost is about $45 per ton in Knoxville ($6 per ton F.O.B. Wyoming). For this reason, only preliminary tests were conducted. In these tests (Table 4), bentonite was both mixed in 6 inches of soil and applied as a blanket. The results show that blanketing is much more effective than mixing. Due to the cost of the clay and the bulk of the material involved, chemical treatments appear to be more practical for most Tennessee conditions.

Table 4. Mean permeability rates in inches per day for soils treated with bentonite

Soil type	Bentonite application rate (lbs./sq. ft.)[1] 0	1	1.5	2	3	6
Bentonite Mixed in Top 6 Inches of Soil						
Armour (Silt Loam, 30-35 in.)	.77	.59	.51	.34	.28	.063
Hartsells (Loam, 10-14 in.)	.50	.22		.128	.04	
Sequoia (Clay, 54-60 in.)	.42				.26	
Bentonite Layer in Permeameter Core						
Armour (Silt Loam, 30-35 in.)	.77		.0036		.0022	

[1] One lb. per sq. ft. equals 22 tons per acre.

FIELD TESTS

Lambe and Anderson (8), in one of the first reports of a large-scale attempt at reservoir sealing by chemicals, outlined the procedures used in sealing a 6.4-acre sulfite liquor storage lagoon in Chisholm, Maine. The seal blanket was constructed in two 6-inch lifts. To each lift sodium tetraphosphate at 1.1 tons per acre was added. The chemical and soil were mixed with a mechanical mixer, and compaction was achieved by six passes of a sheepsfoot roller. The installation was a complete success. Johnson, **et al** (6) reported on sodium pyrophosphate treatments of two leaking ponds in a deep loess area of Iowa. Treatments of 2.2 and 4.4 tons per acre reduced seepage losses to about 20% of the losses before treatment.

Jamison and Thorton (5) in Southwestern Missouri treated two seriously-leaking ponds in highly aggregated red clay with sodium hexametaphosphate. They found that treatment rates of 2 tons per acre produced a satisfactory seal. The Soil Conservation Service (10) described the treatment of sinkhole ponds in limestone areas of Virginia. Clay fills were placed in the sinks up to the levels of the proposed water lines. Sodium tripolyphosphate at 1.1 tons per acre was mixed into the fills, and they were dampened and compacted. The results were satisfactory.

In Table 5 are listed the ponds and treatments of this study. In applying the treatments, the ponds were dry in all cases except for ponds 8 and 9. With these exceptions, the areas below the proposed water lines were disked to a depth of 6 inches or more before chemical application (Figure 4). This required at least two passes of the disk. The chemical was spread uniformly with a spreader (Figure 5). Then the chemical was mixed into the soil by two or more passes of the disk. The treated area was then compacted by several passes of a tractor. In ponds 8 and 9, the bottoms were too wet to support machinery. Here the chemical was spread by hand; and in pond 9, mixing was achieved by pulling a drag through the wet area.

Figure 4. Pond 9 at the Middle Tennessee Experiment Station before application of a chemical.

Table 5. Ponds chemically treated

Number	Location	Year Dug	Year Treated	Chemical	Rate[1]	Soil	Size in acres: Pond	Size in acres: Watershed	Depths[2] in ft.: Max.	Depths[2] in ft.: Min.
1	UT-AEC[3], Oak Ridge	1965	1965	Na_2CO_3	5	Fullerton[4]	0.16	2.2	8.8	8.0
2	UT-AEC, Oak Ridge	1965	1966	$Na_4P_2O_7$	2	Fullerton	0.33	4.6	12.5	10.7
3	UT-AEC, Oak Ridge	1965	1965	Na_2CO_3	5	Fullerton	0.19	4.6	4.6	2.7
4	UT-AEC, Oak Ridge	1963	1964	Na_2CO_3	5	Fullerton	0.42	31.2	13.3	10.6
5	UT-AEC, Oak Ridge	1963	1964	Na_2CO_3	5	Fullerton	0.16	3.0	13.8	6.7
6	UT-AEC, Oak Ridge	1965	1966	$Na_4P_2O_7$	2	Fullerton	0.91	59.5	14.1	5.0
7	Blount Farm, Louisville	1961	1965	$Na_4P_2O_7$	2	Sequoia	0.63	19.8	14.9	10.8
8	Plateau Exp. Sta., Crossville	1960	1965	$Na_4P_2O_7$	2	Hartsells	0.40	8.0	9.3	7.9
9	Middle Tenn. Exp. Sta., Columbia	1961	1963	Na_2CO_3	3.5	Armour	2.37	32.2	8.9	6.8
10	Middle Tenn. Exp. Sta., Columbia	1966		Untreated		Colbert[5]	3.00	275.0	13.0	11.1

[1] Tons per acre-6 in.

[2] Jan. 1 through Nov. 15, 1967. Depth at deepest part of pond.

[3] University of Tennessee—Atomic Energy Commission Agricultural Research Laboratory.

[4] The Fullerton at all sites was cherty.

[5] Some Braxton was also present.

Figure 5. Applying chemical to pond 9 at the Middle Tennessee Experiment Station in October, 1963.

The application procedures used were similar to those of Fonner (3), except that Fonner recommends sprinkling the treated area and compacting it with a sheepsfoot or rubber-tired roller. In the tests reported herein, compaction equipment was not available except for pond 2; the floor of this pond was dry enough to prepare it for chemical application; after the chemical was applied, however, the treated area rapidly became too fluid to achieve compaction.

Before construction, pond 1 was a natural sink which held some water during the winter and spring but which was usually dry during the summer and fall. During construction the depression was deepened, and the excavated material was used in constructing the dam. Immediately after treatment, a serious leak developed in the vicinity of the drain pipe. This was successfully repaired by a procedure described under "Blowouts." Table 5 gives maximum and minimum depths for all ponds during 1967.

Pond 2 held practically no water during the winter of 1965-66. After treatment in May 1966, the level of the pond gradually began to rise; and by July, 1967, it had reached 12 feet.

Pond 3 was a natural sink which held water only during wet seasons. In preparation for treatment, little other than thoroughly disking the area below the proposed water line was done. After treatment, a blowout developed where the staff gage had been installed. This was successfully repaired as described under "Blowouts."

Ponds 4 and 5 had been dug for more than 1 year before treatments were applied. They held practically no water (Figure 6) before treatment. After treatment, they have held rather well (Figure 7); however, pond 5 has such a small watershed it catches little water during seasons of limited rainfall.

Figure 6. Pond 4 at the University of Tennessee-Atomic Energy Commission Agricultural Research Laboratory before treatment in July, 1964.

Before treatment, pond 7 never held more than 1 or 2 feet of water during dry seasons. The soil of this pond was a very highly structured blocky clay. After treatment, it has held well (Table 5).

Although pond 8 held water during the entire year, in seasons of drought the maximum depth of the pond was usually no more than 3 to 4 feet. Table 5 suggests that the treatment has considerably decreased the seepage rate.

Before treatment, pond 9 held not more than 2 feet of water over about one-third of the pond's floor during the fall, and the pond was of little practical value. The pond's lowest depth since treatment in October, 1963 has been 5.6 feet. Figure 8 shows the pond with the water at a depth of 6.9 feet.

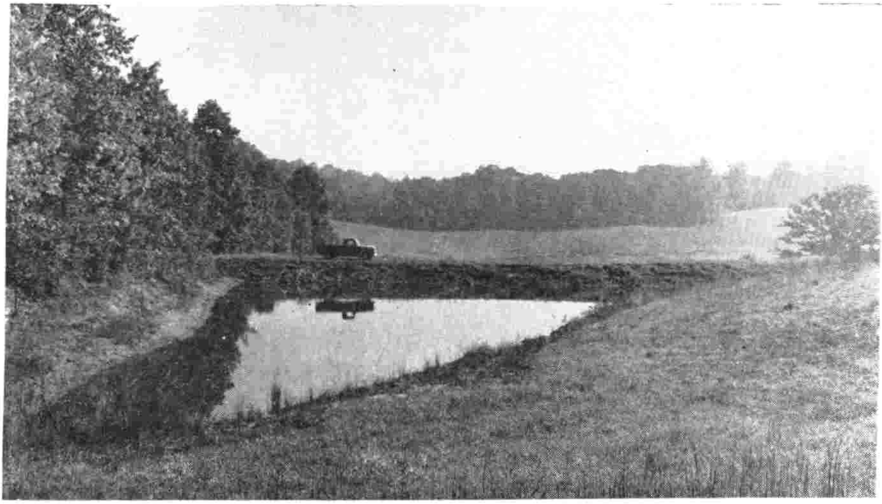

Figure 7. Water in pond 4 at the University of Tennessee-Atomic Energy Commission Agricultural Research Laboratory at a depth of 10.4 feet in October, 1967.

It was anticipated before construction of pond 10 that treatment would be necessary; however, these soils had relatively impervious parent materials. The dam was constructed with a core of relatively impervious material. This core was keyed into the parent material by a 6-foot core trench. Treatment was not necessary in this installation since the seepage rate is low and the watershed is large (Table 5).

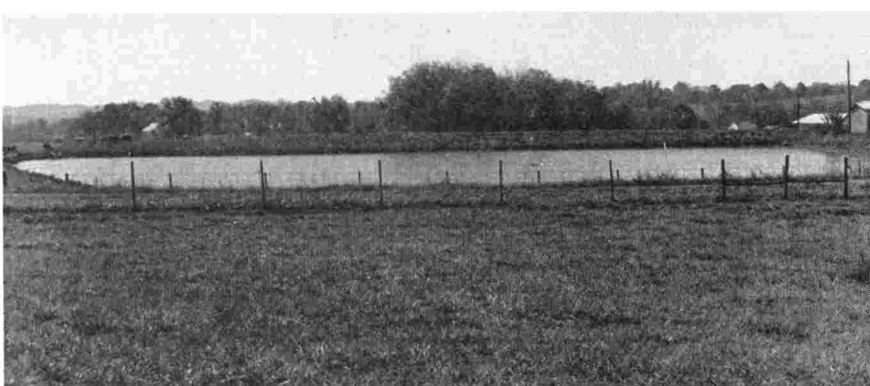

Figure 8. Water in pond 9 at the Middle Tennessee Experiment Station in October, 1967 at a depth of 6.9 feet.

BLOWOUTS

When the seal blanket of a pond lies over pervious material, it must have enough strength to support the hydrostatic head of the pond water, or it will rupture. This rupture is called a blowout. Blowouts often occur when the seal blankets are over gravel, chert, limestone, sandstone, or other porous materials. The chemical sealing process depends on dispersing the soil forming the seal blanket. Thus chemical treatments reduce the structural strength of the soil, and blowouts are more likely to occur. The thickness of seal blanket necessary to prevent blowouts is not definitely known.

A series of laboratory tests were conducted where treated samples were compacted in 3-inch diameter cylinders over 5/8-inch diameter glass spheres to simulate gravel. The cores were compacted to about 90% of Standard Proctor density, and a head of 10.67 feet was applied. Some of the soil samples were pulverized, and others were sieved through 1/2-inch mesh. The tests were conducted on cores between 6 and 12 inches in length to determine if the compacted cores would withstand the head applied. Table 6 summarizes the results of the blowout tests.

Table 6. Results of simulated blowout tests

Soil and Horizon	Mechanical Treatment	Chemical[1] Treatment	Core Depth (in.)	Days of test	Number of Trials: Blowout	High[2] K	Satisfactory[3] K
Armour	Pulverized	Na_2CO_3	6	22	3		
(Silt Loam	Pulverized	$Na_4P_2O_7$	6	128		3	
30-35 in.)	Pulverized	Na_2CO_3	9	77			2
	Pulverized	Na_2CO_3	12	54		1	1
	Pulverized	$Na_4P_2O_7$	12	128			3
Fullerton	Pulverized	Na_2CO_3	6	33	1		1
(Cherty Clay	Pulverized	$Na_4P_2O_7$	6	33			1
24-30 in.)	Pulverized	Na_2CO_3	9	33			2
	Sieved[4]	$Na_4P_2O_7$	6	7	2		
	Sieved	$Na_4P_2O_7$	6	330		3	
	Sieved	$Na_4P_2O_7$	12	330		2	1
Hartsells	Pulverized	$Na_4P_2O_7$	6	35			3
(Loam	Pulverized	$Na_4P_2O_7$	9	35			1
10-14 in.)							
Sequoia	Pulverized	Na_2CO_3	9	563			1
(Clay	Sieved[4]	Na_2CO_3	6	580		2[5]	1
54-60 in.)	Sieved	Na_2CO_3	9	580		1[5]	

[1] Na_2CO_3 and $Na_4P_2O_7$ treatments were at 5 and 2 tons per acre 6 in., respectively.
[2] K between 0.10 and 0.012 in./day.
[3] K of 0.012 in./day or less.
[4] Sieved through one-half inch mesh.
[5] K between 0.30 and 0.10 in./day.

All blowouts occurred in the 6-inch depth cores. Of the 8, 12-inch cores tested, 5 had K rates of less than 0.012-inch per day. Of the 11, 6-inch cores of sieved soils tested, only one had a K rate as low as 0.012-inch per day. This again points out the advantage which may be gained from good mechanical break-up of soils before applying a chemical treatment. Table 6 suggests that at least 1 foot of well-compacted, relatively impervious material over porous areas of pond floors is necessary to prevent blowouts under a head of 10 feet. Fonner (3) suggests covering rock outcrops and pervious areas with at least 2 feet of good material and compacting it well.

In the field tests, blowouts occurred in ponds 1, 3, and 6. In pond 1, a serious leak developed in a chert stratum near the drain pipe. This was repaired by blanketing the leaking area with about 2 feet of clay and then treating the blanket. The pond has since withstood heads up to 8.8 feet, and it now holds well (Table 5).

A staff gage was installed in the bottom of pond 3. At a stage level of about 2 feet, the pond blew out where the gage was installed. At the hole, only about 8 inches of fines lay above a chert stratum. The hole was plugged with clay and treated, and the pond has since withstood heads of 4.65 feet.

Soon after construction, pond 6 developed leaks (Figure 9) in a chert stratum along one side of the pond at levels of about 5 feet above the bottom of the pond. In preparing the pond for treatment, the leaks on the side were blanketed with about 2 feet of fines from the bottom of the pond. After treatment, the pond developed a blowout in the bottom (Figure 10). Too much fine material had been removed from a weak portion of the bottom because the pond had withstood a head of 10.3 feet before attempt was made to repair the leaks in the side of the pond.

In June, 1967 about 600 cubic yards of clay fill material were hauled to pond 6, and it was spread and compacted with a bulldozer. The weak area was blanketed with about 1½ feet, and the remaining portion of the pond up to a depth of about 5½ feet was blanketed with ½-foot of fill material. The pond has since withstood a head of 14 feet in a severe storm without developing a blowout in the blanketed area. The blanket was treated with Na_2CO_3 at 5 tons per acre. The pond still leaks above the blanketed level; however, the water level has not been below 5.0 feet since 10 days after the pond was repaired.

Figure 9. Leak into chert stratum in pond 6 at the University of Tennessee-Atomic Energy Commission Agricultural Research Laboratory, July, 1966.

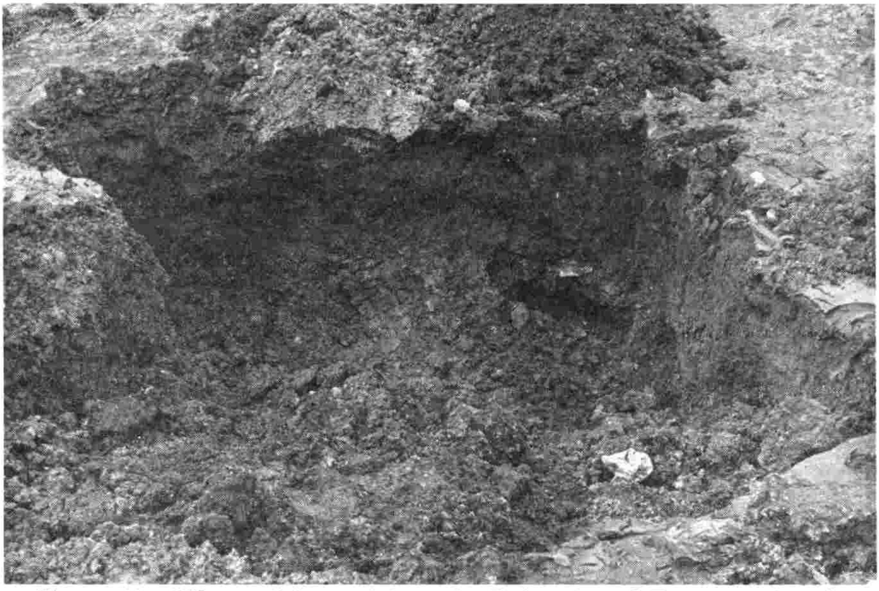

Figure 10. "Blowout" in pond 6 at the University of Tennessee-Atomic Energy Commission Agricultural Research Laboratory, November, 1966. The leaking area was excavated with a backhoe. Note the leakage cavity in the right rear of the excavated hole.

TURBIDITY

In a treated pond having little or no overflow, the pond water is usually quite turbid (muddy) immediately after treatment. After a period of several months, most treated ponds become clear or nearly so. Since the clarity of pond water depends on the condition of the watershed, ponds having barren or cultivated watersheds may never become clear.

In 1967 turbidity determinations were made by a candle turbidimeter according to standard procedure (2). Table 7 gives a summary of 12 periodic determinations made on (8) ponds. All ponds were quite turbid after treatment. None of these ponds had discharge through the spillway or trickle tube except during periods of prolonged heavy rainfall.

Table 7. Summary of Turbidity data, 1967

Pond Number[1]	Year Treated	Chemical	Rate	Mean Turbidity Units[2]	
				March-April	July-October
1	1965	Na_2CO_3	5	134	131
2	1965	$Na_4P_2O_7$	2	330	72
3	1965	Na_2CO_3	5	96	24
4	1964	Na_2CO_3	5	15	5
5	1964	Na_2CO_3	5	37	5
7	1965	$Na_4P_2O_7$	2	311	195
9	1963	Na_2CO_3	3.5	98	------
10	Untreated		0	12	------

[1]See Table 5 for complete description of ponds.
[2]High turbidity readings indicate turbid (muddy) water. Pond water samples having readings of 25 or fewer units are usually considered "clear."

By the July-October period of 1967, the 2 ponds treated in 1964 were almost "clear." Of the 4 ponds treated in 1965, the turbidity decreased between the March-April and the July-October 1967 periods. Based on these tests, the water in the treated ponds has tended to become "clear" in about 2 to 3 years.

PERMANENCE OF TREATMENTS

In the sealing treatments of this study, an exchange of sodium for the calcium adsorbed on the soil particles took place. The sodium-saturated system became dispersed. The physical re-orientation of these dispersed soil particles resulted in the sealing. The results of the field tests suggest that the sealing effects are relatively permanent. Lambe (8) reported that the leakage rate of a lagoon treated in Maine decreased with time.

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